slightly adjustable magnification, a reciprocally moving illumination system, and a photomask articulated within its frame to introduce slight relative motions in two dimensions. This combination of elements involving the moving optical system and the intermittently stationary photomask and format solves the notable problems of previous designs in a simple manner. There is plenty of room to use a large reflective achromatic optical system and still scan a large format, the two-dimensional effects of distortion are removed, the introduction of yaw angle error is avoided, and the web is fed through the machine without twisting or stress. It is designed to produces high-resolution images (better than 2 micron least dimension) everywhere on the format and ~~better than 1 micron~~ layer to layer overlay accuracy in the micron region. The optics are completely achromatic and the system is therefore insensitive to the wavelength composition of the light which is supplied by the illuminator.

[019] Autofocus is maintained by two proximity sensor gages and two servoed lifters, one under the object field and one under the image field. Optionally the photomask is carried in a vacuum support frame that helps to maintain the image surface flat, countering sag due to gravity. However, since focus is performed independently ~~on~~ in each field, and corrected independently ~~on~~ in each field, the object end of the apparatus can ride over a considerable residual curvature in the photomask without image degradation or change in magnification. For a similar reason, the image end of the optical train can also tolerate considerable variation in the level of the format plane.

[050] The two concave primary mirrors 4, 5 are used because the system is required to change magnification by up to one part in 10^3 to compensate for possible Y direction format distortion. These two elements are flex mounted and provided with a piezo or

micro-stepper drive 16 (Fig. 12) so that they may be driven reciprocally axially up to [±20μ] ±20 microns, one forward, the other back. This reciprocal motion produces the necessary magnification change without any significant image degradation. When one mirror is moved inward and the other outward, one conjugate of the system shortens, the other lengthens by the same amount and the magnification changes by the ratio of conjugate distances. Small spherical mirrors are among the least expensive precision optical elements. Thus the two smaller primaries are less expensive and, of course, lighter than a single larger mirror.

[071] The photomask/platen assembly 39 and the section of web that it grips are driven the width of one raster scan 40 (Fig. 11) in the short interval between reciprocating passes 38 of the optical transfer assembly 1 across the format. This intermittent forward movement 40 is about 80 mm. the height of the good field when an optical system such as the example given herein in Table 2 is in use. This intermittent yet fairly precise motion can best be accomplished using a lead screw and stepper motor or a linear motor in an open-loop drive 48.

[083] Alignment gages are used when one is writing a second or higher layer over the first recorded pattern or layer that exists on the web. In that situation it is necessary that the subsequent patterns superpose over the base pattern accurately enough so that the functional characteristics of the circuit are maintained. ~~In a panel this may require accuracy in superposition to around 1 micron.~~ A plastic format plane as large as 18 x 24 inches is liable to severe and essentially unpredictable distortion, estimated to be as large as 1 part in 10^4, due to humidity, heat, mechanical stretching and processing. This error

can amount to 50 microns or more. The occurrence of at least 10-20 microns of distortion is expected.